Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 202 (2015) 424 – 435

Procedia
Social and Behavioral Sciences

ASEAN-Turkey ASLI (Annual Serial Landmark International) Conference on Quality of Life 2014, ABRA International Conference on Quality of Life, AQoL2014, 26-28 December 2014, Istanbul, Turkey

Maximization of IBS Elements at Wet Areas in Solving Leaking Problems and Promoting Better Quality Control

Nurul Asra Abd Rahman[a*], Zainab Mohmad Zainordin[a], Suryani Ahmad[b], Noorsaidi Mahat[c]

[a]*Centre of Studies for Construction, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.*

[b]*Department of Building, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 32610 Bandar Sri Iskandar, Perak, Malaysia.*

[c]*Department of Building, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 94300 Kota Samarahan, Sarawak, Malaysia*

Abstract

A practice of adopting In-situ concrete (ISC) construction method for wet areas in pre-cast concrete (PC) buildings to overcome leakage problem is a setback for full IBS adoption. Various options explored while developing ideal solution only to discover the answer is possible within the existing parameters of IBS. The proposal adopts composite construction comprised of metal permanent formwork and ISC casting for toilet floor, while PC components remained as buildings structural framing system. This proposal combined different elements of IBS systems offers all the advantages associated with IBS; minimize wastages, better quality, shorter construction period and minimized unskilled workers.

Peer-review under responsibility of AMER (Association of Malaysian Environment-Behaviour Researchers) and cE-Bs (Centre for Environment-Behaviour Studies, Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia.

Keywords: Industrialised Building Systems; Hybrid technology; Pre-Cast Structure; leakage at wet area

[*]Corresponding author. Tel.: +6-035-544-4267; fax: +6-035-544-4353.
E-mail address: asra@salam.uitm.edu.my.

Peer-review under responsibility of AMER (Association of Malaysian Environment-Behaviour Researchers) and cE-Bs (Centre for Environment-Behaviour Studies, Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia.
doi:10.1016/j.sbspro.2015.08.247

1. Introduction

Industrialised Building system (IBS) is defined as a construction process that utilizes building components or system, which involve prefabricated components and on-site installation. Improve perception on adoption of IBS in Malaysia is attributed by initiative by the federal government through IBS roadmap programs to modernize the construction industry and to reduce the conventional in-situ method of construction which requires many unskilled foreign workers. The adoption of IBS offers valuable advantages such as the reduction of unskilled workers; less wastages; less volume of site materials; improve site cleanliness; reduce environmental pollution; better quality control; promote site safety practice and reduce construction time. Structural classification under IBS roadmap falls into five (5) main categories namely: precast concrete framing/panel and box systems; formwork systems; steel framing systems; prefabricated timber framing systems and block-work systems. (Mohammad M.F., 2013). Among the five (5) structural categories, three (3) systems are concrete related construction because concrete is by far the most preferred materials in Malaysia. Precast Concrete (PC) framing system, panel and box system that utilize prefabrication technology fit the definition of IBS as compared to formwork systems which still involve on site activities. A case study by Bari et al. (2012) shows that prefabrication technology of PC framing/panels and block-work system if conceptualized at early design stage can provides significant advantages over conventional in-situ system such as reduction in construction time by 35%, less skilled labour requirements and construction cost savings of more than 10%, and improved quality control. Because of the advantages, IBS essentially promotes sustainable construction (SC) whereby building construction activities are responsible for creating and maintaining a healthy environment and human health through efficient of resources. The SC process should involve during planning stage until the building is handed over to the client (Isnin et al. 2013).

One of the limitations of adopting PC is water seepage problem. A survey by Building and Construction Authority (BCA) Singapore in 2003 BCA (2014), shows that precast joints are the weakest links in ensuring water tightness which include joints between precast elements as well as joints between precast elements and other fittings (Kamar et al. 2007). Leakage also occurs through construction joints and cold joint because different cast of concrete will not bond properly due to different stage of setting and hardening times. Unfilled joints of 1 to 5mm width between precast floor panels need in-situ concrete topping to close the gap and to achieve flat floor surface, thus creating cold joints between precast elements and in-situ topping. Natural cement shrinkage during building life cycle will further widen the cold joints marginally and water leaks through this open joints. The leaking problem is more profound for wet areas that are constantly exposed to water such as toilets, balconies, pantries etc. Exposing in ages of concrete structure to the dampness will deteriorate its quality and strength. It is a common practice is to adopt a hybrid of in-situ reinforced concrete (IRC) and PC within the same building with the IRC used for wet areas and PC used for the remaining areas. Hybrid system or mixed system, according to Lachimpandy et al. (2011), is considered as amalgamation of IBS and the conventional construction. Conventional in-situ system, despites being the least efficient, is by far the most widely used in Malaysia. IBS which is still at infancy stage and not preferred by most contractors, therefore adoption of mixed system is seen as an intermediate construction method which can slowly reduce the gap between IBS and conventional construction. The initial objective of this research is to develop a revolutionary jointing system in PC components that can solve leaking problems and for use at toilets and wet areas. This is to reduce or eliminate the use of IRC method of construction.

2. Precast concrete and joint sealants

Concrete joints are designed to help alleviate contraction, expansion, cracking, and vertical movement of concrete. Concrete joints are also used between different stages of concrete casting. Joints between pre-cast concrete (PC) components provide physical separation between each panel which is necessary because PC components have to be of manageable size so that they can be manufactured in factory, transported on public road and erected on site. Sealants are typically designed or applied to resist hydrostatic forces at PC joints to provide watertight seal (Box Culvert 2013). Sealing of PC joints is to prevent ingress of water and air into buildings. Connections between precast concrete components can be in simple butt joints, lap joints or tongue and groove joints. Sealing methods between PC joints can be open-drained, face-sealed and compression-sealed (NPCAA – 2012). Many types of sealant materials are available for different applications. However polyurethane (single and multi component) and

single component silicone are two (2) most commonly used sealant materials for sealing joints between PC components (SIKA, Brochures 2010-2014). Sealant does not bond properly on wet and porous surfaces like concrete and usually needs base primers as adhesive to avoid premature failure (CCPCI 2010). The life span of sealant materials varies under different climatic conditions and it is often shorter for application under tropical climate due to continuous exposure to excessive heat, moisture and humidity. Most manufacturers offer limited product warranties on all their sealant products.The warranties cover specific periods (5-10 years) and come with strict technical conditions. Warranties will be null and void if works were not done in accordance withtheir standard manufacturers' instructions. Sealant works best under compressiontherefore it is suitable for use during vertical stacking application whereby the self weight of PC upper panels compresses the sealants on the PC lower panels. Common uses of sealant for horizontal application in PC components are as expansion joints and contraction joints (NPCAA – 2012). Sealant is not commonly used to seal joints between PC floor panels inside buildings because the narrow gaps of 1 to 5mm between each panels make it impossible to apply any types of sealants effectively. In-situ concrete topping above the PC slabs which is part of structural requirement to resist lateral movement is used instead to close the gaps and to create flat floor surface. Mechanical and electrical services can be embedded into the in-situ structural topping (BCA, Singapore 2012). Unfortunately this method is susceptible to cracks which causes leaking problem due to formation of cold joints between PC slab and in-situ topping resulted from different stages of concrete casting. The above observations show that the initial objective of this research to develop a revolutionary jointing and sealant systems may not offer long term solution to solve leaking problem in PC structure.

3. Causes of leaking for toilet in precast concrete structure

Methodology used in this research to determine the cause of leaking for toilets in PC structure is through meta-analysis by combining results from multiple studies to reduce any uncertainty. Different methodologies adopted were;

- Interview sessions with stakeholders related to PC namely; IBS Centre, IBS manufacturers, IBS installers, and IBS consultants.
- Literature reviews and formulation from recent and previous researches related to leaking problems in PC buildings.
- Site inspections on PC buildings which had experienced leaking problems.

In consensus, consistent with site observations and research findings by Rahman et al (2013) and Chew et al. (2014), all stakeholders agreed that the most common causes of leaking for toilets and wet areas in concrete frame building, regardless of PC or IRC constructions are;

- Leaking through cracks (major structural cracks or non-structural hairline cracks).
- Leaking through pipe sleeves penetration,
- Leaking through cold joints of concrete which are not monolithically casted,
- Poor workmanship for installation of waterproofing system.

Based on site observations and consistent with findings by Li et al, (2009) and Kamar et al. (2007), stakeholders in consensus agreed that the leaking problems for toilets and wet areas are more prevalent in PC structure as compared to IRC structure due to;

- Structural cracks caused by movement between precast concrete components namely, column beam and slab.
- Cold joints between precast slab and in-situ concrete topping.
- Sanitary pipe sleeves which penetrated through preformed openings of precast slab. The pipes are placed and casted at later stage of construction together with in-situ concrete topping.
- Hairline cracks ofin-situ concrete topping.

According to CIDB, previous attempts to use PC slab for toilets in PC frame building had been unsuccessful. Observations during earlier attempts managed to identify the causes of leaking. It was observed that PC structure is not rigid and is always prone to cracks when subjected to structural movement caused by imposed dead loads, live loads and lateral forces during buildings natural life cycle. Due to formation of cracks by the structural movement, revolutionized jointing system of PC components as originally intended may not offer long term or permanent solution to leaking problem.

According to Rahman et al. (2013) in Malaysian context, IRC is still the preferred method of construction for toilets and wet areas in PC structure with two (2) most common approaches namely;

- The whole toilet supporting structural elements such as columns, beams and slabs adopt full IRC construction,
- The columns and lower half of beams remain asPC while only the top of beam and slab adopt IRC.

The use of IRC method of construction for toilets in a PC frame building often slow down the progress of work, increase material wastages, produce lower quality of work and increase man power. Somehow, the hybrid of the two (2) systems defeats the noble intention on full adoption of IBS. Therefore, another method of construction should be explored to maximize the IBS content. The alternative method of construction should be able to address the issues on maximization of IBS usage and solve the leaking problem often associated with PC structure. Some of the factors are;

- Structural framing system for column and beam should remain as PC,
- The whole floor slab for the toilet areas ideally should be monolithically casted in one pour of concrete together with any pipe penetration to eliminate any form of construction joints or cold joints,
- Design of toilet should not be limited to domestic type of buildings but also to cater for larger toilets in other type of buildings such as commercial, institutional, industrial etc.
- To explore usage of other IBS components among different structural categories of IBS roadmap such as, precast concrete framing/panel and box systems; formwork systems; steel framing systems; prefabricated timber framing systems; and block work systems.

4. Proposed solution to leaking problem for toilet and wet areas in precast concrete structure

4.1. Typical toilet design

A typical toilet design had been developed for the purpose of this research using common toilets in main block of FSPU, UITM, in Shah Alam as a basis. Slight modification had been made to the design for practical reasons. Some of the features to the toilet design were:

- Both male and female toilets confined to a column grid of 6mx6m area,
- Both male and female toilets shared a common service shaft for easy maintenance access,
- All water closets (WC) to use pedestal type (sitting) with P-trap outlets which are connected to the main sanitary pipes that run horizontally inside the common service shaft. This is to minimize vertical pipe penetration through slab,
- All internal wall partitions within the toilet area to use lightweight aerated concrete block. This is to avoid the need for secondary internal support beam underneath the 6mx6m grid toilet floor slab.

Typical toilet design is as shown in figures 1 and 2.

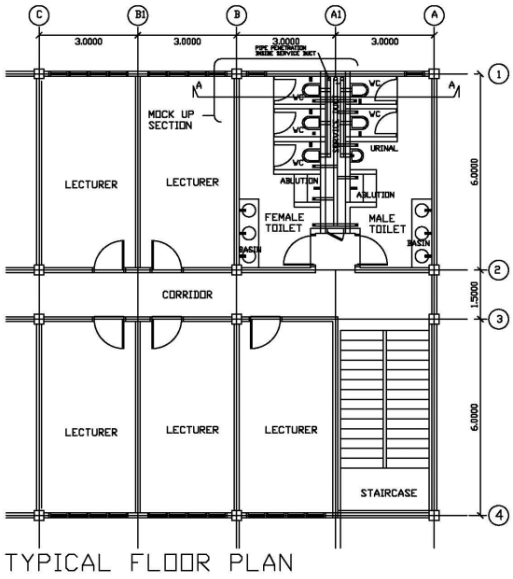

Fig. 1.Floor plan of toilet design.

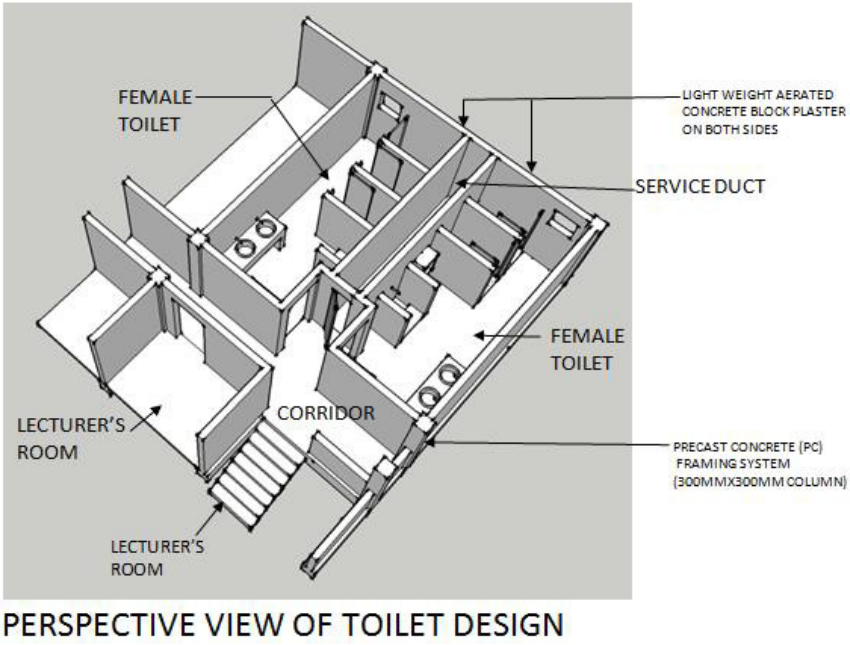

Fig. 2.Perspective view of toilet design.

4.2. Possible solutions

Based on research by Rahman et al. (2013), under the most ideal circumstances of IBS application, the whole toilets should be constructed as a complete Prefabricated Toilet Units (PTU). PTU which is commonly used in aircraft and ships construction is also widely used for residential building in other developed countries including Malaysia nearest neighbour, Singapore. However, usage of PTU in local context is limited to outdoor portable toilet units and medium sized stand alone public toilet buildings. So far, based on IBS Centre records, no PTU had been successfully developed under mass production for commercial usage inside buildings. This is probably due to lacks of awareness and readiness of the market to adopt PTU. Public are familiar and have strong preference for in-situ toilet which is considered to offer greater design creativity and flexibility. Due to logistic reasons, PTU is only suitable for small to medium sized toilets and therefore not feasible for adoption at larger toilet which had been developed for this research.

Another possible solution is to use PC panel technology whereby the whole 6mx6m concrete floor slab of the toilet is treated like a concrete tray and to be fabricated under a controlled factory environment together with pipe sleeves and electrical conduits embedded into it. The waterproofing application and water flooding test can also be done in factory prior to delivery to site. However, logistic factor for transportation of the 6mx6m slab from factory to site and hoisting it from the ground into the building will be a major setback. Therefore this option is also not feasible.

4.3. Final proposal

The final proposal which explore the use other elements of IBS structural systems is a combination of PC and metal permanent formwork system. The proposal is for the whole floor slab for the toilets within the 6mx6m column grid to be constructed using composite construction comprises of metal permanent formwork and in-situ concrete slab while the columns and beams remain as precast concrete framing system. The suitability of this proposal in term of compliance to IBS requirement and offer solution to leaking problem is based on the following observations;

- Metal permanent formwork even though often uses with steel framing system, it is also suitable for use with precast concrete framing system (BHP LysaghtBondek @11 web site),
- Metal permanent formwork which come in standard width and can be cut to any length to suit any size and shape. It can easily cover the whole 6mx6m toilet area,
- Steel reinforcement for the whole slab above the metal permanent formwork can be integrated and secured to the exposed reinforcement of perimeter beams thus creating one monolithic system for the toilet. This can minimize possibility of structural cracks.
- The whole slab thickness above the metal permanent formwork can be casted in one concrete pour without the need of in-situ concrete topping, thus eliminating any cold joints.
- On-site installation of sanitary pipe sleeves and electrical conduits can be incorporated with the steel reinforcement and cast into the concrete slab in one monolithic system, thus reduce the possibility of leaking.
- Essentially, the whole metal permanent formwork floor and precast concrete perimeter beams offer similar characteristics as in-situ concrete method of construction without the need for temporary formwork. Elimination of temporary formwork would translate to shorter construction time; reduce wastages and less pollution to surrounding environment.

Images of final proposal are as shown figures 3 and 4.

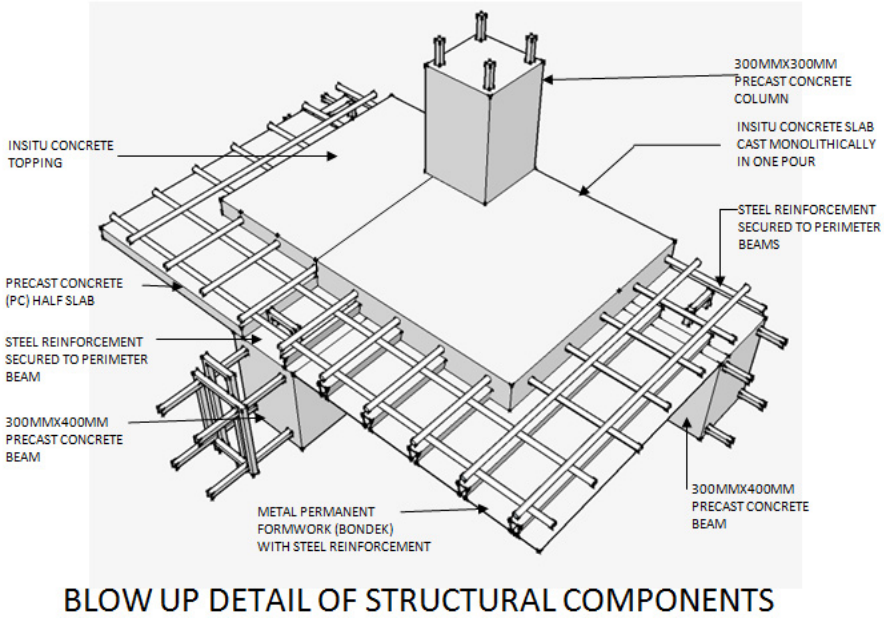

Fig. 3. Blow up detail of final proposal.

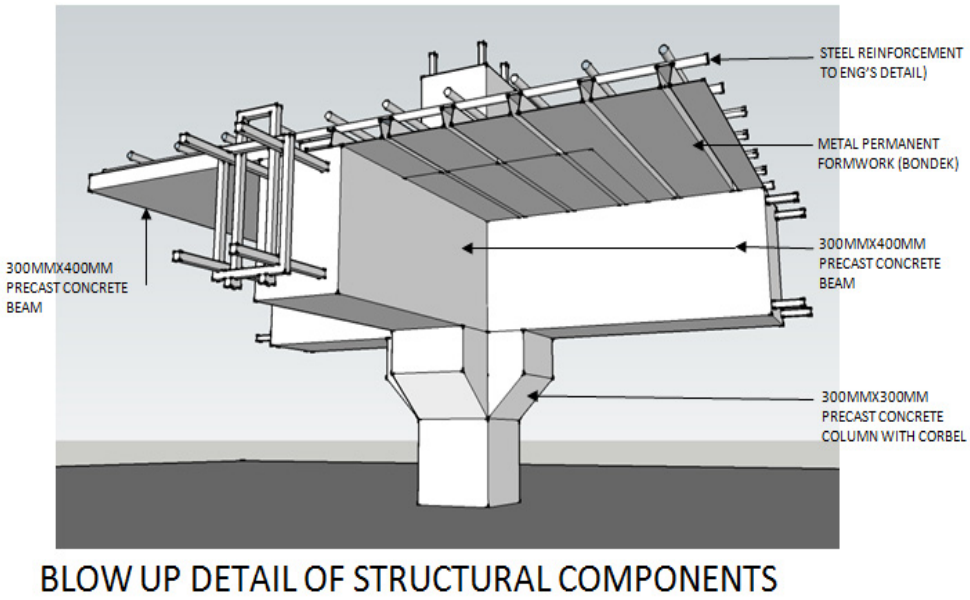

Fig. 4. Blow up detail of final proposal.

5. Mock up of proposal

To prove the suitability of the final proposal, a mock up had been constructed to conduct water flooding test against leakage. Instead of constructing the whole 6mx6m column grid area and the immediate surrounding areas, only a small section of the final proposal had been constructed as mock up. This is to focus on critical areas of possible leaking namely:

- Intersection between different PC components,
- Intersection between metal permanent formwork and perimeter PC beams,
- Intersection between metal permanent formwork, perimeter beams and adjacent PC half slab,
- Joints between composite slab above metal permanent formwork and adjacent in-situ concrete topping,
- Intersection of masonry wall composite concrete floor slab,
- Pipe penetration for main sanitary pipe and floor waste pipe,
- Joints between monolithic casting of concrete composite slab and in-situ topping.

Since only a small section of the proposal had been constructed as mock up, temporary masonry walls and columns had been constructed to support the PC beam, PC half slab and metal permanent formwork. Up-stand wall at the height of 150mm to match with waterproofing level had also been constructed to contain water during flooding test. Due to site constraint and cost limitation, PC components for column and corbel had been built using in-situ method, while PC beams and PC half slab had been fabricated at adjoining sites and hoisted into place using a backhoe machine. Nevertheless, the concept and sequence of work for PC framing structure had been strictly adhered to.

While developing the final proposal, there is no intended collaboration with any specific brand of products. However for this mock up, BHP LysaghtBondek@II had been used as material for the metal permanent formwork due to availability of technical specification and guidelines especially for maximum span of supports and acceptable region for pipe penetration. For the waterproofing system, cementitious SIKA Brush Coat had been used. Plan and images of mock up is as in figures 5, 6 and 7.

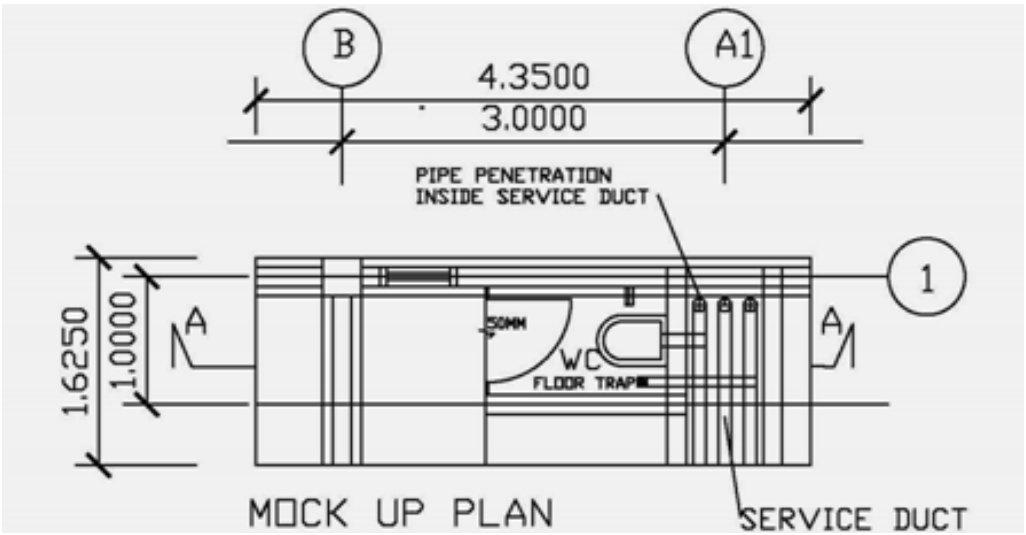

Fig. 5.Floor plan of mock up.

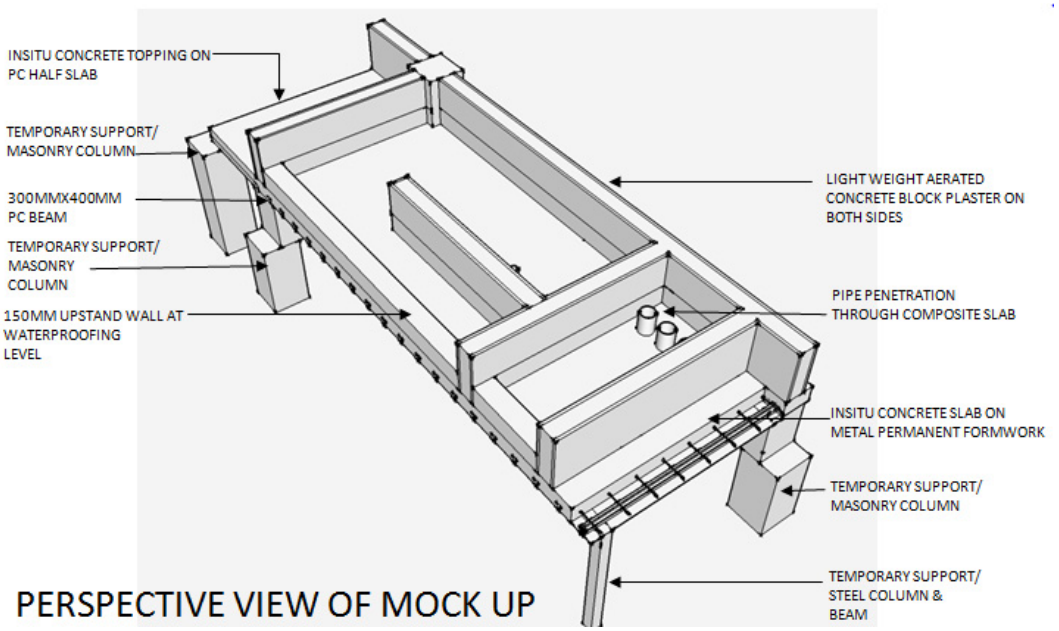

Fig. 6.Image of mock up.

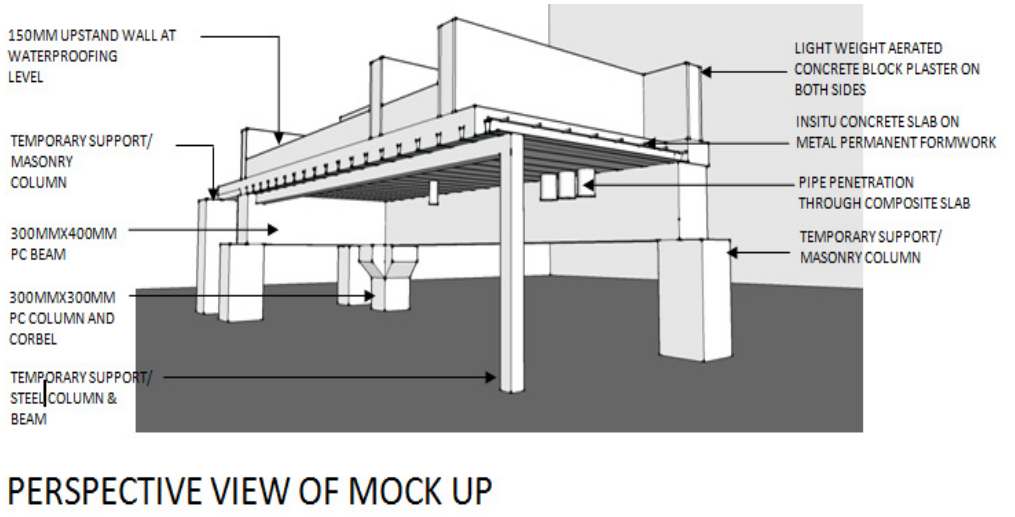

Fig. 7.Image of mock up.

5.1. Observation on flooding test of mock up

Water flooding test is the most common method use in construction industry to identify water tightness against leaking whereby water is flooded inside toilet areas. Any sign of leaking is then observed outside the flooded area usually for a period of one (1) month. However for better accuracy, this mock up had been subjected to flooding test for an extended period of three (3) months. This is to allow for structural movement or settlement of PC

components. A temporary tent cover using two (2) layered plastic had been constructed to avoid outside water such as rain from entering the flooded area and to reduce condensation of water due to direct exposure to heat and sunlight.On first day of testing, watermarks were found on external wall surfaces flooded area. The wall surfaces remained wet and damp for three (3) days and dried up after the fourth day. Initial observation showed that water seeped through wall surfaces above 150mm waterproofing level. The leaking stopped after the water level dropped below the 150mm waterproofing level.The water flooding test was inspected twice per week for the three (3) months period. At the end of first month, it showed very positive results whereby;

- No major structural cracks due to movement of PC components'
- No major hairline cracks of in-situ concrete topping,
- No water mark outside waterproofing area,
- No water drip below metal permanent formwork,
- No water drip through pipe penetration.

This proved that the mock up had been properly constructed. Similar results were observed at the end of second month observation period. Slight drop of water level below the 150mm mark was discovered and was suspected from effect of minimal condensation resulted from heat generated below the plastic tent cover. At the end of the third month observation period, again showed similar results with no water mark or water drip outside the water flooding area. There was no need for topping up of water into the flooded area since the drop in water level due to condensation was insignificant.

6. Conclusion- effectiveness of final proposal against leaking

Upon completion of three months observation period for water flooding test, it can be concluded that the proposal to use metal permanent formwork as floor base of toilets in PC structure is feasible. It complied with the context of IBS requirements in Malaysia. The metal permanent formwork basically replaced PC half slab or PC slab which also functioned as permanent formwork.This proposal which combined three (3) IBS construction systems namely; precast concrete framing system, metal permanent formwork and modular concrete masonry blocks offers all the advantages of IBS system such as environmentally friendly, reduced material wastages, shorter construction time, reduced manpower and produced high quality of work. However the success of this proposal requires careful planning during design stage and strict supervision during construction stage. This is consistence with the finding by Ismail et al. (2012), which suggests that good coordination between all parties in management factors for every stage of IBS play the main role as the pulse towards success of any IBS projects. Ismail et al. (2013) also emphasize improvement in site management system of IBS construction which includes work place, work team, safety, materials and equipment contribute to success of IBS projects. This is to ensure the technical aspects of the proposal are carefully monitored namely:

- Steel reinforcement over metal permanent formwork floor are secured properly to the perimeter beams for monolithic casting of concrete,
- Location of pipe penetration must be within the acceptable region to suit the technical design of metal permanent formwork,
- Casting of concrete must be done in one pour to avoid any formation of cold joints,
- Water proofing application must be done strictly in accordance to manufacturer's instructions to ensure water tightness,
- Mixing, casting and curing of concrete must follow good engineering practice and during favourable weather condition to ensure good quality of in-situ concrete,
- Sufficient structural drop or reduced level of perimeter beam is required to accommodate various drops in the design of toilets. The various finished levels or floor drop inside the toilet can be achieved with different thickness of floor screed.

Technically, based on the flooding test result, the proposal is feasible for adoption. However other factors such as aesthetic and financial grounds also need to be considered:

6.1. Aesthetic

Aesthetic consideration may be subjective. However it could still influence the selection of a construction system.

- The soffit of slab for permanent formwork with exposed metal surface may not be aesthetically acceptable to everyone. Compared to exposed concrete surface which can be plastered and painted, exposed metal permanent formwork may appear to be unfinished. For aesthetic reason, false ceiling may be required to cover the soffit of metal permanent formwork surface.

6.2. Financial

Financial issues are often the main contributing factors in selecting a construction system. Some of the financial issues are:

- Metal permanent formwork is more expansive than conventional temporary formwork. Cost of metal permanent formwork and composite slab is comparable to PC half slab and in-situ concrete topping construction. However, the transportation and installation cost of metal permanent formwork is considerably less.
- Metal permanent formwork still requires temporary props at certain interval to support weight of wet concrete and construction loads. This is to avoid deflection during casting of concrete. While the props can be removed and re-used for subsequent casting of concrete, it becomes a permanent asset to the contractor which still adds to the initial cost.
- For those who are not familiar, metal permanent formwork may appear like a specialist trade. Any unskilled workers can be trained to familiarize with the method of construction. Training and familiarization process may add to the overall cost.
- False ceiling to cover the soffit of metal permanent formwork will involve additional cost.
- Light weight aerated modular concrete block is considerably more expansive than conventional masonry units such as clay bricks or cement/sand bricks. However the increased cost can be offset from the omission of any secondary beams which are required when conventional masonry walls are used.

The original objective of this research is to develop a revolutionary jointing system in PC structure to solve leaking problems for use at toilets and wet areas. However, the final proposal adopted a different approach which combined different categories of IBS also met the same objective of solving the leaking problem.The adoption of this hybrid method of constructions not only promotes maximization of IBS usage but also solve leaking problem in PC structure particularly at toilet and wet areas. Most importantly, it also contributes towards achieving the main objective of IBS roadmap which is to reduce the dependency on the unskilled foreign labour through modernization of the construction industry. Modernization of construction industry as a whole will improve the quality of work through reduction of in-situ construction activities and wet trades on site. IBS when embraced in total can contribute to better quality of life.

Acknowledgements

The authors would like to thank En.Rofizlan Ahmad from IBS Centre of CIDB and En.Ahmad Hazim Abdul Rahim from CREAM of CIDB for the information regarding IBS. Thanks to En. Tun Abdullah Zamil for helping the author in field supervision and monitoring of mock up.Special thanks to the KementerianPendidikan Malaysia (KPM) for funding this research via Research Management Institute (RMI), Development Department of UniversitiTeknologi MARA.

References

Bari N.A.A, Abdullah N.A., Yusuff R., Ismail N., Jaapar A. (2012). Environmental Awareness and Benefits of Industrilized building Systems (IBS). *Procedia Social and Behavioral Sciences*, 50 (2012) 392-404.

Building Construction Authority (2012). Building and Construction Authority Singapore. *Design Concept for Precast System*. Retrieved on 6th August 2012 from bca.gov.sg.

Building Construction Authority (2014). Building and Construction Authority Singapore. *Design of External Wall*. Retrieved July 18, 2014 from http://www.bca.gov.sg

Canadian Precast-Prestressed Concrete Institute (CPPCI - 2010) - *Architectural Precast Concrete Sealant Joint Guide 2010*.

Chew M.Y.L., Nayanthara D.S., Tan S.S. (2014). Maintenability of Wet Areas of Non-residential Building. *Structural Survey*, 22(1), 39-52

Ismail F., Yusuwan N.M., Baharuddin H.E.A. (2012). *Management Factors for Successful IBS Projects Implementation*. *Procedia Social and Behavioral Sciences*, 68 (2012) 99-107.

Ismail F., Baharuddin H.E.A., Marhani M.A. (2013). Factors towards Site Management Improvement for Industrilised Building System (IBS) Construction. *Procedia Social and Behavioral Sciences*, 85 (2013) 43-50.

Isnin Z., Ahmad S.S., Yahya Z. (2012). *Building Material Management Framework for Greener Adaptation Projects*. Asian Journal of Environment-Behaviour Studies, Volume 3, Number 8, April 2012.

Kamar K.A.M., Hamid Z.A., . Ghani M.K., & Rahim A.H. (2007). Industrilized Building Systems: *Current Shortcomings and the Vital Role of R&D. 2nd Quarter Master Building Publication*.

Lachimpadi S.K., Pereira J.J., Taha M.R., Mokhtar M. (2012). Construction Waste Minimisation Comparing Conventional and Precast Construction (Mixed System and IBS) methods in High-rise Buildings: *A Malaysia Case Study.Resources, Conservation and Recycling,* 68 (2012) 96-1-3.

Li K., Li C., Chen Z. (2009). Influential depth of Moisture Transport in Concrete Subject to Drying-Wetting Cycles, *Cement & Concrete Composite*, 31, 693-698.

Lysaght. (2014). Structural Products. BHP Lysaght Bondek @11. Retrieved on July 18, 2014 from http://www.bluescopelysaght.com.my

Mohammad M.F. (2013). Construction Environment: Adopting IBS Construction Approach towards Achieving Sustainable Development. *Procedia Social and Behavioral Science*, 85 (2013) 8-15.

National Precast Concrete Association Australia (NPCAA -2012) Precast Concrete Hand Book 2012.

Precast Concrete Box Culvert Joint Sealant Guidelines. Retrieved on 30th June 2013 from www.boxculvert.com.

Rahman N.A.A., Ahmad S., Zainordin Z. (2013). *Perception and Awareness of Leaking for Toilet in Pre-cast Concrete Structure*. Procedia Social and Behavioral Science, 85 (2013) 61-69.

SIKA Malaysia - Technical brochure 2000-2014.